International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN (P): 2249–6890; ISSN (E): 2249–8001
Vol. 11, Issue 4, Jun 2021, 57–66

FEASIBILITY STUDIES AS AN IMPORTANT PART OF PLANNING FOR HYBRID RENEWABLE ENERGY SYSTEM (HRES) PROJECTS: CASE STUDY CITY OF UMHLATHUZE

MELUSI NHLEKO & FREDDIE L. INAMBAO*

Department of Mechanical Engineering, University of KwaZulu-Natal, Durban, South Africa

ABSTRACT

Electricity supply shortages in South Africa are a result of poor strategic planning in relation to energy forecasting. This unfortunately has compromised the security of supply of the country which negatively affects its economic stability. Feasibility studies may be viewed as a tedious and expensive exercise, but they are necessary to develop strategies to resolve the country's energy crises. Feasibility studies in the energy sector would enable accurate and informed procurement of hybrid renewable energy technologies. To further aid planning, Benchmarking, as suggested by the South African Local Government Association, is also a useful planning tool. Effective feasibility studies depend on the efficiency of procurement systems, adequate policies and funds being available. This paper proposes the capacitation of the planning departments in municipalities through the formation of renewable energy project teams that comprise technical, legal, finance (procurement) and project/contract management personnel in order to effectively address complex energy problems and related project issues. The details of any hybrid renewable energy system (HRES) project can be accurately outlined after a feasibility study has been conducted and concluded.

KEYWORDS: Feasibility Studies, Hybrid Renewable Energy System (HRES) & PV-MFC Hybrid Technology

Received: Apr 20, 2021**; Accepted:** May 10, 2021; **Published**: Jun 14, 2021; **Paper Id.:** IJMPERDAUG20215

Original Article

1. INTRODUCTION

The assertiveness and commitment required from the South African government in taking a leadership role in resolving the country's energy challenges is to pursue the full exploration of renewable energy sources for generation and supply purposes. Together with the municipal Supply Chain Management (SCM) and Public Private Partnership (PPP) policies in place, the country can be rated among other world-class (developed) countries that have the capacity to satisfy high energy demands, thus being able to reliably and sustainably cater for fast growing economic trade activities at affordable rates that promote 'clean' energy and improve the quality of life of citizens.

To accelerate change and prevent complacency, municipalities must, according to this study, review their current operation in relation to the growing demand for services and economic development. Municipalities must take aggressive strides to improve their infrastructure in order to reach a stage of sustainable and reliable delivery of services to the community. Municipalities should reach a stage where they are able to market their infrastructure capacity to adjacent communities and potential investors by attracting economic investments through offering world class infrastructure and energy capacity. Thus, municipalities are urged in this study to urgently and comprehensively audit reasons for existing infrastructure challenges, determine the state of infrastructure, conduct feasibility studies on remedying the infrastructure conditions through rehabilitation and refurbishment projects, and

implement agreed upon cost effective measures that eradicate energy wastage and improve infrastructure conditions. In doing so, all benefits associated with good infrastructure conditions such as energy conservation and efficient use of energy will be the order of the day.

Since the scourge of insufficient energy persists, municipalities must be encouraged and supported by both national and provincial government spheres to generate energy from renewable sources within their municipality such as biomass resources collected at treatment plants. Municipalities must be encouraged to conduct feasibility studies as part of their planning towards preparing for electricity generation implementation. The pre-treatment phase which comprises of removing impurities, plays a fundamental and crucial role in the effective success of generating electricity. Thus, the success and efficiency of the pre-treatment process of biomass is dependent on the careful scrutinizing and management of all pre-treatment processes and technology requirements, and subsequent generation requirements.

Excessively high energy bills are incurred by municipalities in order to provide basic services. The need to provide these services results in excessive energy demand from the national grid, and yet some measures can be implemented to arrest energy wastage and uncapped consumption. Unchecked performances generally lead to disastrous outcomes that, unfortunately municipalities choose to live with rather than find meaningful solutions that ensure that basic services are provided at affordable rates. Imagine a municipality that has a wastewater treatment plant or a water treatment plant that has not been modified by installing energy saving (efficiency) devices and respective infrastructure not made anew through rehabilitation/refurbishment projects, the municipal equipment or facilities tend to be intense energy consuming resulting in excessively high bills. Now, if a municipality is in possession of a number of such facilities or equipment that have not been reconditioned and modified to be energy sensitive or efficient, the municipality is capable of incurring exorbitant bills. Having a number of municipalities country-wide with facilities that are in poor condition and have no energy efficiency devices installed, what effect do the collective municipalities have on the national grid and economy of the country, end-users or beneficiaries of basic services provided by municipalities, and the impact on affordable functioning of municipalities? The importance of periodic energy and infrastructure audits is highlighted as possible measures in addressing identified challenges or issues.

System efficiency must not be a reactive process of gathering data on energy bills and trending energy demand and consumption, but must be planned before-hand so that all variables can be factored in and modelled to improve system efficiency performance. The process of gathering data must be used as a tool for checking performance and not for planning performance, because the culture of gathering data and attempting to improve performance in most cases results in misdiagnosis, procurement of misaligned technology, lack of commitment by government and other government institutions or departments, and negative attitudes from government personnel in procuring and operating technologies and systems that can be beneficial as well as loss of opportunity to correct or modify system behaviours that result in improved systems. Hybrid systems such as photovoltaic microbial fuel cells (PV-MFC) offer the advantage of reduced capital or investment costs yet provide effective multiple functions when employing reviews that re-model and factor in parameters that improve the viability and performances of the PV-MFC hybrid system.

Promethium Carbon and the South African National Energy Development Institute (2017) state that in order to access clean and stable energy and meet sustainable development goals in the energy sector, migration by developing countries from fossil fuel dependency to renewable energy source(s) engagement is necessary. Access to and financing of renewable energy projects are major challenges for many developing countries such as South Africa, but PPP agreements

together with using well structured financing models that account for discounted future value of renewable energy projects in terms of money and socio-economic impact is a step in the right direction.

This paper reflects the benefit of a PV-MFC hybrid system that addresses electricity generation and supply challenges within the context of relevant legislation which is designed to conserve the environment for present and future generations. Strict adherence to legislative prescripts ensures that there is no alteration of the ozone layer that permits dangerous levels of solar energy, and alteration of the natural water environment (ocean) which then destroys the marine ecosystem.

The appointment of a Transactional Advisor (TA) as soon as possible is necessary for the municipality to achieve it's set goals and those of the national government of all citizens having access to electricity by year 2030. The implementation of this hybrid renewable energy system (HRES) based project would reduce the trend and consequences of non-expenditure on allocated budgets. The location of the City of uMhlathuze in relation to the above indicated available renewable sources, together with available municipal land, makes the municipality a good candidate for improved energy bills, and improved delivery of essential services at affordable rates to itself and surrounding communities from use of renewable sources along with reduced greenhouse emissions. However, limitations to this study are the financial resources required to appoint a TA that would comprise professional legal institutions, professional financial institutions or agencies and a professional technical team that will conduct feasibility studies at professional fees which are unaffordable at this stage of this research work.

Although the country faces a lot of energy and socio-economic challenges which drag the country into a pit of lost hope and ailing confidence, the call by government for joint efforts in solving the country's energy crises provides the motivation for this paper, of having the municipality decrease demand from the national grid, generate its own electricity using renewable energy hybrid technology to power its treatment plant, reduce energy bills, have adequate and sustainable security of energy supply, thereby enabling the municipality to function in a reliable manner and deliver services as mandated.

The national treasury (NT) guide together with Eskom's 2020 annual financial report indicate that government's guarantee towards resolving energy challenges and related issues is R300 billion of which a sum or amount of R274 billion has already been committed in resuscitating Eskom's plans of improving the energy supply of the country. Immediate robust pursuit of as many feasibility studies as possible regarding hybrid renewable energy generation implementation at municipal institutions is of paramount importance using the guide provided by this paper of uMhlathuze municipality, and the utilization of the remainder of the government's guarantee of R26 billion over a 2-year budget cycle, will fast-track the gaining of global investor confidence in the country and achievement of the 2030 energy targets. In the context of this paper, PV-MFC hybrid technology is deemed viable to power the wastewater treatment plant in uMhlathuze municipality, and constructing such a facility at up-scaled magnitudes will take 7-9 years, thus making it possible to meet the envisaged 2030 target. The evaluations and guide arising from this paper are proposed to enable the implementation of PV-MFC renewable projects at the municipality from feasibility to construction and commission stages.

2. BACKGROUND

This study provides an overview of the importance of creative thinking in the energy sector and how innovative exploration of renewable energy sources is an important and crucial advancement in the present energy standing of South Africa. This

provides insight into how energy sustainability can be implemented to improve reliability of municipal treatment facilities through the use of HRES.

Considering the broadness of the subject area of generating electricity at municipal institutions using renewable energy sources, detailed feasibility studies must be conducted for each of the category A and B municipalities (as described by the Municipal Finance Management Act [MFMA], [South Africa, 2003]) that have already established good customer based profiles, excellent electricity revenue collection data and trends, and have competent high performing electricity planning sections that implement energy related projects effectively. Examining the above mentioned indicates the health of the municipality's business profile on electricity related matters, thus the capacity of the municipality to implement and operate specialised mega renewable energy projects. Although it has become a norm that planning divisions or sections in municipalities are generally concerned with planning and implementing operations and maintenance projects, the research and development (R&D) aspect of planning gets neglected to the extent that procurement of technology is based on convincing presentations by marketers of technology rather an objective feasibility studies, often resulting in the purchasing of ineffective technology.

One of the limitations of this research study is the lack of leadership and commitment by government 'municipal' personnel in allocating and committing necessary budgets that can facilitate the undertaking of detailed feasibility studies that will assist the municipality in dealing with its energy challenges. Thus, initiatives such as conducting regular infrastructure monitoring exercises together with installing devices that seek to improve energy efficiency are lacking.

The following is a compilation of recommendations arising from the study. The recommendations fall into two categories:

- Energy improvement strategies recommended for the municipality to implement in line with world class energy saving policies and targets, with the following generic solutions proposed:
- Introduction of energy efficient equipment as an energy saving strategy;
- Improvement of infrastructure conditions and performance as an energy conservation strategy; and
- Technological advancement as an energy intervention strategy to improve efficiency and reduce energy consumption.
- Establish research and development (R&D) strategies for municipalities to utilise and implement benchmarking measures regarding energy saving with high performing institutions globally. R&D seeks to propose meaningful endeavours for the purpose of gaining approvals and finding lasting solutions through, among others, the use of the latest technologies. Proposed solutions are:
- Allocation of dedicated human resources such as energy planners, procurement officers, legal practitioners and project/contract management personnel.
- Allocation and commitment of financial resources towards the planning (conducting of feasibility studies) and implementation of R&D recommendations, and
- Organisational (executive) commitment and participation in the examination of technologies so as to enable proactive decisions and approval of best-suited technologies.

Emphasising the above view, South African Local Government Association (SALGA) an institution that was established to support and aid municipalities, in their 2015 annual report recommended the following:

- Process (or best practice) benchmarking, where municipalities search for and study other municipalities, utilities or organisations that are high performers in particular areas of interest. In so doing, municipalities are able to gather information about similar infrastructure and what processes, practices and procedures they have adopted in keeping their infrastructure in acceptable condition. These processes, practices and procedures are studied and knowledge gained is taken back to the municipality and where feasible and appropriate, these good practices are adopted and incorporated into the municipality's own processes. Process benchmarking therefore allows municipalities to understand why other municipalities are performing better in delivering services, keeping good infrastructure conditions, and consequently resulting in energy bills free from waste.
- Metric (or performance) benchmarking involves municipalities comparing the performance levels of municipalities using performance indicators for a specific process such as energy conservation, infrastructure condition and performance standards, infrastructure preservation, sustainable delivery of services through reliable infrastructure, etc. The information gathered is used for identifying opportunities for improvement, setting performance targets and understanding relative positioning in comparison to other municipalities. Metric benchmarking allows municipalities to assess the performance of various aspects of their business processes and systems and determine which of their activities are weak or strong, and how much improvement can be made.

Municipalities are urged to benchmark against high performing similar institutions or with other international local government institutions, but the Council for Scientific and Industrial Research (CSIR) (2007) report on the state of municipal infrastructure in South Africa indicated that among other things, municipalities compare poorly in respect of strategic planning, asset accounting and making financial provisions for improvement of infrastructure condition and resolving energy related challenges.

The core of this study is gaining the depth of understanding required of water and wastewater schemes and plants, even if they are of conventional make-up, to use for the purpose of making the municipal facilities energy self-sustaining so that services are effectively delivered and bills reduced. This will enable the municipality to determine the effectiveness of prescribed or proposed strategies in yielding desired efficiency improvements and energy savings, and by how much. These energy-saving and energy-bills-reducing strategies are grouped and recommended as follows:

A. Generic Energy Efficiency Equipment Related Strategies

- Kowalska-Pyzalska and Byrka (2019) describe the power factor as being how effectively a facility utilizes all of the electrical power it acquires. Kowalska-Pyzalska and Byrka (2019) further state that the demand components (kVA) within the bulk electricity tariffs are directly affected by the power factor of operation. Therefore, the power factor is in the interests of the consumer, in this case the municipality, and must be kept as close to unity as possible because the kVA of operation increases as the power factor decreases resulting in the customer paying higher network demand charges and higher network access charges than necessary. Low power factors are caused by inductive loads such are induction motors, and in order to compensate for these inductive loads, capacitive components commonly known as power factor correction capacitors are introduced into the system. In other words, the municipality must improve the typical power factor of 0.85 to 0.95 or 0.995 for all induction motor dominant

loads. Thus, recommendation of to install power factor correction capacitors.

- Automate all component systems or components that can be automated for the purpose of improving efficiency.
- Due to low performing and poor infrastructure conditions, refurbish and/or replace all redundant or aged infrastructure with parts or components that will have an improved allowable life.
- Install energy management and performance monitoring systems or devices together with bulk check meters and/or zone meters to configure the baseline.
- Install variable speed drives where possible.
- Monitor and regularly lubricate all moving components and change and/or refill oil in gearboxes and cylinders. Check, repair and refill all leaks in hydraulic cylinders and tubes.
- Repair and maintain all mechanical components, and audit conditions of all electrical components and check for efficiencies and replace when necessary.
- Recondition or replace aged or weak windings as they tend to be a major source of energy wastage. eplace aged and faulty circuit breakers.
- Recondition or replace pumps with new and improved pumps to improve pumping system efficiency. Pump efficiency can differ in definition depending on the various parameters used to determine efficiency, however, pump efficiency is critically dependent on maintenance and operational aspects. Decision-making and pump selections must take into consideration energy efficacy and low operational and maintenance costs. Optimal energy savings can be achieved by combining newer, more efficient pumps with variable speed drives and with high efficiency motors.

B**. Generic Energy Conservation Based on Human Behaviour Strategy**

- Capture accurate data of plant performance in terms of plant efficiency, infrastructure and energy management and modelling in order to achieve optimal performances based on extensive historical records.
- Schedule periodic infrastructure and energy auditing of plant and corresponding energy performances, and arrange for appropriate works.
- Conduct annual benchmarking exercises with similar type world class institutions for latest best practices and standards.
- Allocate adequately skilled labour to detailed operational functions, and allocate competent skilled and semi-skilled labour to repair and replace faulty or dilapidated parts or fixtures for water treatment plants, water abstraction weirs and pump station plants. Skilled operators must at all times use the electricity usage index and consumption measurements as tools at the various plants to identify problem areas as this exercise facilitates more efficient energy management (cost saving) and improved environmental impacts.
- Adopt an established, detailed organizational Energy Management Strategy (EMS) that links throughput, plant processes and energy management, and other areas of facility management into an integrated approach especially during unplanned emergencies and load-shedding.

- Upgrade electricity grid and installation of consumption metering in real time, and a management system. Identify units with high energy consumption during maximum demand periods when high tariffs apply.
- Negotiate and have an annual review of tariffs and supply lines where possible for reduction of energy bills.
- Shift the off-work periods of identified equipment to time spans when lower tariffs apply.
- Maintain supply MVA against set point MVA, revert to load shedding when exceeding set point.
- Install energy sensitive devices where necessary. Include energy saving devices on high energy consuming parts and parts that have high maximum energy demand during periods when tariffs are high.

Er (2016) is of the view that in order to evaluate the effective impact and performance of a technology, "simulation", "economic evaluation-payback model" and "data analysis and planning" processes must be undertaken with an established appropriate funding schemes in place such as a PPP. The 2019/2020 annual uMhlathuze municipality report reflected that the municipality has a 99 % revenue collection rate on its electricity. Bearing in mind the view expressed by Promethium Carbon and the South African National Energy Development Institute (2017) that PV-bioenergy hybrid systems can have a payback period of between 4 to 6 years after commencement (depending on financial models and fees agreed upon with the financial institution to fund the HRES project), installation of a PV-MFC hybrid system can be lucrative for the municipality and can be pursued with great confidence as HRES projects offer cheaper electricity rates and a shorter payback period.

Based on the views of Pakenas (1995) that wastewater treatment plants consume large amounts of energy but also have the capacity to produce large amounts of energy from sewage sludge, Hampton (2007) states that the process of harvesting energy from natural reserves such as from human waste for the purpose of generating electricity is important as municipal facilities mainly collect sewage largely comprising of human waste. The use of improved appropriate hybrid technologies such as a PV-MFC hybrid system deserves investment in order to enhance energy generation. Baker and Philips (2019) state that the time has come to challenge the conventional electricity utility business model which is based on a centralised system of generation, transmission and distribution, through the use of disruptive technologies (innovations that when scaled up cause disruption to the basic architecture of the electricity generation system) and 'prosumer' (producer-consumer) electrification. When a disruption occurs in a centralised system the whole grid (nation) gets affected whereas when disruption occurs in a decentralised system, the problem is localised in that area. The benefits of decentralised generation are reduced repair time, reduced transaction costs and reduced impact on the general economy, etc. Atkins et al. (2017) propose decentralised generation and distribution of the primary grid component with smaller macro-grids being supported by mini-grids.

3. RECOMMENDATIONS

The following suggestions and recommendations drawn from the study are put forward for future research.Since MFC technologies together with improvement measures for MFCs are mainly at laboratory scale and have been unproven for implementation at large scale in the South African market, and PV technologies are efficient but very expensive to implement on a large scale, feasibility studies are required to determine:

- The characteristic properties of microbes (since they are location specific) found on the north-east coast (Indian ocean) of South Africa must be examined, and how that group of bacteria can contribute to the generating of current in MFCs.
- Cheaper but efficient materials for internal proton transfer in MFCs that can easily be operated and maintained.

- Cheaper pure or alloy materials that concentrate solar energy and convert solar energy to electrical energy but generate little or no heat energy that gets dissipated as heat in the solar module.

Conducting the above detailed feasibility studies require specialists in the field and highly specialised and fully equipped research institutions, so at the writing of this paper were beyond the scope of this study. Such studies must be conducted and handled with suitable funding and sponsorship. Emanating from the 2007 CSIR report on the state of municipal infrastructure in South Africa, further studies must be undertaken to understand why municipalities compare so poorly in respect of strategic planning, asset accounting and making financial provisions for improvement of infrastructure condition and resolving energy related challenges.

4. CONCLUSIONS

In the absence of detailed feasibility studies, complex energy related issues may often result in misdiagnosis and procurement processes that are later met with objections. Thus, to eliminate resistance of any form and to gain committed support or backing from the executive, stakeholders and general citizenry, municipal planning departments must be properly capacitated and equipped for the task of conducting effective planning functions through feasibility studies emanating from R&D.

REFERENCES

1. *Atkins, P., Hasley, R. and Schubert, T. (2017). Renewable energy resources: Transforming our energy future. Project 90 by 2030.*
2. *Sunny K Darji, Jigar K Parmar & Gajendra R Patel, "Energy Storage System with Multilevel Inverter for Distributed Grid Application",International Journal of Electrical and Electronics Engineering (IJEEE) ISSN(P): 2278-9944; ISSN(E): 2278-9952 Vol. 7, Issue 3,pp, 1-16*
3. *Baker, L. and Phillips, J. (2019). Tensions in the transition: The politics of electricity distribution in South Africa. Environment and Planning C: Politics and Space, 37(1), 177-196.*
4. *Jigar K. Parmar, Sunny K. Darji & Gajendra R. Patel, "Fuzzy Based MPPT Controller of Wind Energy Conversion System using PMSG",International Journal of Electrical and Electronics Engineering (IJEEE),Vol. 7, Issue 3, pp, 17-30*
5. *Council for Scientific and Industrial Research (CSIR). (2007). The state of municipal infrastructure in South Africa and its operation and maintenance: An overview. Pretoria: CSIR.*
6. *Er, Z. (2016). A study of evaluation of solar energy simulation and modeling systems. International Conference on Computational and Experimental Science and Engineering. Acta Physica Polonica A. 130(72), 72-77.*
7. *B. Saleh & M. S. Youssef, "A Parametric Analysis of an Ejector Refrigeration Cycle Activated by Renewable Energy"International Journal of Mechanical and Production Engineering Research and Development (IJMPERD),Vol. 9, Issue 3,pp, 1143-1156*
8. *Hampton, P. E. (2007). Methane and cogeneration technology: Renewable energy opportunities for Erie County wastewater treatment plants. University of Buffalo. Retrieved from https://hdl.handle.net/1813/73271*
9. *Kowalska-Pyzalska, A. and Byrka, K. (2019). Determinants of the willingness to energy monitoring by residential consumers: A case study in the city of Wroclaw in Poland. Energies, 12(907), 1-20.*
10. *J.S. Ashwin & N.Manoharan, "Renewable Energy Based Micro-Grid System for Power Quality Improvement ",International Journal of Mechanical and Production Engineering Research and Development (IJMPERD),Vol. 8, Issue 1, pp, 883- 888*

11. *South Africa, Department of National Treasury. (2003). Local Government: Municipal Finance Management Act (MFMA) and Regulations. No 56, 2003. Retrieved from https://www.gov.za/documents/local-government-municipal-finance-management-act-0*

12. *Pakenas, L. J. (1995). Energy Efficiency in Municipal Wastewater Treatment Plants. New York State Energy Research and Development Authority. Retrieved from file:///C:/Users/Richard/AppData/Local/Temp/Energy-Efficiency-Municipal-WWTP.pdf*

13. *Promethium Carbon and South African National Energy Development Institute. (2017). Technical report: Appraisal of implementation of fossil fuel and renewable energy hybrid technologies in South Africa. Retrieved from https://www.sanedi.org.za/img/wp-content/uploads/2018-01-15%20Hybrid%20Technologies%20in%20South%20Africa%20full%20report.pdf.*

14. *South Africa Local Government Association (SALGA). (2015). Annual report on water services in South Africa: The municipal benchmarking initiative. Institution of Municipal Engineering of Southern Africa and Water Research Commission. Retrieved from https://africacheck.org/wp-content/uploads/2017/03/Municipal-Benchmarking-Initiativeannual-report-2015.*

15. *uMhlathuze Municipality. (2020). 2019/2020 annual report. Retrieved from https://www.umhlathuze.gov.za/index.php/financialstatutory-reporting/35-financial-statutoryreporting/136-annual-r*